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ASSESSMENT OF BIOTIC INTEGRITY USING FISH COMMUNITIES

James R. Karr

ABSTRACT

Man's activities have had profound, and usually negative, influences on freshwater fishes from the smallest streams to the largest rivers. Some negative effects are due to contaminants, while others are associated with changes in watershed hydrology, habitat modifications, and alteration of energy sources upon which the aquatic biota depends. Regrettably, past efforts to evaluate effects of man's activities on fishes have attempted to use water quality as a surrogate for more comprehensive biotic assessment. A more refined biotic assessment program is required for effective protection of freshwater fish resources. An assessment system proposed here uses a series of fish community attributes related to species composition and ecological structure to evaluate the quality of an aquatic biota. In preliminary trials this system accurately reflected the status of fish communities and the environment supporting them.

Passage of the Water Quality Act Amendments of 1972 (PL 92-500) stimulated many efforts to monitor the quality of water resource systems. Unfortunately, these efforts concentrated on development of thresholds and criteria levels for specific contaminants, often based on acute toxicity tests. The use of these criteria has been attacked on numerous grounds (Thurston et al. 1979); for example, they have not taken into account naturally occurring geographic variation of contaminants (e.g., asbestos, iron, zinc), considered the synergistic effects of numerous contaminants, nor considered sublethal effects (e.g., reproduction, growth) of most contaminants. In addition, monitoring of water quality parameters (nutrients, DO, temperature, pesticides, heavy metals, and other toxics) often misses short-term events that may be critical to assessment of biotic impacts. Finally, it is impossible to measure all factors that may impact biotic integrity. In fact, much literature on chemical contaminants is of questionable value for setting water quality standards for aquatic organisms (Gosz 1980). Chemical monitoring misses many of the man-induced perturbations that impair use. For example, flow alterations, habitat degradation, heated effluents, and uses for power generation are not detected in chemical sampling. In short, criteria that emphasize physical and chemical attributes of water are unsuccessful as surrogates for measuring biotic integrity (Karr and Dudley 1981).

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Recent legislation (Clean Water Act of 1977, PL 95-217) clearly calls for a more refined approach when pollution is defined as "the manmade or man-induced alteration of the chemical, physical, biological, and radiological integrity of water." Despite this refinement, regulatory agencies have been slow to replace the classical approach (uniform standards focusing on contaminant levels) with a more sophisticated and environmentally sound approach.

The integrity of water resources can best be assessed by evaluating the degree to which waters provide for beneficial uses. Important uses as defined by society may include water supply, recreational, and other uses as well as the preservation of future options for the use of the resource. Since an ability to sustain a balanced biotic community is one of the best indicators of the potential for beneficial use, sophisticated monitoring programs should seek to assess "biotic integrity."

This paper describes a procedure for monitoring water resources using fish. My contention is that by carefully monitoring fishes, one can rapidly assess the health ("biotic integrity") of a local water resource. In short, carefully planned monitoring and assessment can rapidly and relatively inexpensively serve as an exploratory assessment of water resource quality. Where impaired use is suggested by biological monitoring, a more nearly complete monitoring program can be implemented in search of the causative agent(s).

WHY MONITOR FISH?

Biological communities reflect watershed conditions since they are sensitive to changes in a wide array of environmental factors. Many groups of organisms have been proposed as indicators of environmental quality, but no single group has emerged as the

favorite of most biologists. Indeed, in the best circumstances, a biological monitoring program should be based on an integrative approach involving evaluation of several major taxa. However, limited funds and time for assessment argue for a more restrictive approach.

Diatoms (Patrick 1975) and benthic invertebrates (Resh and Unzicker 1975; Hilsenhoff 1977; Mason 1978) have most frequently been cited as ideal organisms for biological monitoring programs. Fish are common as bioassay organisms (Sprague 1973), but they have rarely been used in comprehensive monitoring (but see Hocutt and Stauffer 1980). Efforts to use fish in field monitoring have been directed toward bioassay of contaminants, often using representative important species (USEPA 1977), or, when broader objectives are involved, they have concentrated on sport or commercial species.

Taxa other than fish (macroinvertebrates, diatoms) have been widely used in monitoring because of the availability of a theoretical substructure that allows an integrated ecological approach (Cummins 1974; Vannote et al. 1980). However, use of diatoms or invertebrates as monitoring targets has major deficiencies. For example, they require specialized taxonomic expertise; they are difficult and time-consuming to sample, sort, and identify; background life-history information is often lacking for many species and groups; and the results obtained by using diatoms and invertebrates are difficult to translate into values meaningful to the general public.

Fish, on the other hand, have numerous advantages as indicator organisms for biological monitoring programs. These advantages include

1. Life-history information is extensive for most fish species.
2. Fish communities generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and include foods of both aquatic and terrestrial origin. Their position at the top of the aquatic food web in relation to diatoms and invertebrates also helps to provide an integrative view of the watershed environment.
3. Fish are relatively easy to identify. Technicians require relatively little training. Indeed, most samples can be sorted and identified at the field site, with release of study organisms after processing.
4. The general public can relate to statements about conditions of the fish community.
5. Both acute toxicity (missing taxa) and stress effects (depressed growth and reproductive success) can be evaluated. Careful examination of recruitment and growth dynamics among years can help to pinpoint periods of unusual stress.
6. Fish are typically present, even in the smallest streams and in all but the most polluted waters.
7. Finally, the results of studies using fish can be directly related to the fishable waters mandate of the Congress.

A number of disadvantages of monitoring fish can also be cited. These include the selective nature of sampling, fish mobility on diel and seasonal time scales, and manpower needs for field sampling. But these are disadvantages associated with any major taxa. My objective is not to imply that fish are easy to sample and identify. Rather, I emphasize that, on a comparative basis, training periods for fish identification are likely to be shorter and the technology required is less sophisticated than for other taxa. Field sampling may be slightly more costly, but laboratory time will be relatively small. Obviously, all monitoring programs (physical, chemical, and biological) are expensive and time consuming. My purpose here is to suggest that regular use of fishes will improve the resolution of monitoring and assessment programs.

Table 1. Biotic integrity classes used in assessment of fish communities along with general descriptions of their attributes.

Class	*Attributes*
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with full array of age and sex classes; balanced trophic structure.
Good	Species richness somewhat below expectation, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g., increasing frequency of omnivores); older age classes of top predators may be rare.
Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
Very Poor	Few fish present, mostly introduced or very tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.
No Fish	Repetitive sampling fails to turn up any fish.

Table 2. Parameters used in assessment of fish communities. *(See text for discussion.)*

Species Composition and Richness
Number of Species
Presence of Intolerant Species
Species Richness and Composition of Darters
Species Richness and Composition of Suckers
Species Richness and Composition of Sunfish (except Green Sunfish)
Proportion of Green Sunfish
Proportion of Hybrid Individuals
Ecological Factors
Number of Individuals in Sample
Proportion of Omnivores (Individuals)
Proportion of Insectivorous Cyprinids
Proportion of Top Carnivores
Proportion with Disease, Tumors, Fin Damage, and Other Anomalies

THE CLASSIFICATION SYSTEM

I have been working in a series of watersheds in two midwestern states for seven years with the objective of developing a monitoring system using fishes. The purpose of this paper is

to outline that system as well as to provide a few samples of its use. At this point, I urge caution in applying it in wholesale fashion without further testing. I hope that this report will stimulate other biologists to react to the system, perhaps even try it out in their areas, and thereby aid in its improvement.

I initially set out to develop a system with four discrete classes *(Excellent, Good, Fair, Poor)* to evaluate fish communities. However, after using the system for a time, I found it necessary to expand the system to a total of six classes with the addition of *Very Poor* and *No Fish* groups (Table 1). In many regions in North America it is difficult or impossible to find sites with excellent fish communities. This argues even more effectively for implementation of a monitoring program similar to the one proposed here.

Many of the terms used in these descriptions are qualitative at best. Effective implementation of a monitoring program like this one requires development of more quantitative criteria. Some guidelines for those criteria are described below.

THE CLASSIFICATION CRITERIA

Prior efforts to monitor and evaluate biotic communities typically involved use of only one or two criteria, often combined in an index. Examples include diversity indices (Shannon and Weaver 1949), which consider number of species (richness) and equitability (abundance of species). Others have used production (or biomass) as a single index (Boling et al. 1975) or in combination with diversity (Gammon 1981). These approaches overlook many important variables and thus oversimplify exceedingly complex systems. Another approach to monitoring involves efforts to evaluate attributes of ecological systems—redundancy, inertia, elasticity, and resilience (Holling 1973, Cornell et al. 1976, Cairns and Dickson 1977, Stauffer et al. 1978). My approach is designed to assess the present status of the community using twelve fish community parameters (Table 2). These parameters can be roughly grouped into two sets: Species Composition and Richness, and Ecological Factors.

Species Composition and Richness

The choice of species richness and total number of individuals as primary criteria is obvious, as long as those metrics are weighted by biogeographic, season, and stream-size considerations. For example, a headwater stream in Illinois might be expected to support 10–15 species while a large midriver situation in the same watershed might routinely support twice as many species in a similar length of stream. I avoid use of the most commonly used community metric (species diversity) because it combines two factors (richness and equitability). Both occur directly in the present system.

In addition, diversity measures typically ignore the species composition of sampled communities; the identity of the component species is irrelevant to the index. With the present system several species composition metrics are evaluated. Each fish species has characteristic tolerances for water quality, habitat, and other conditions. Indeed, within each family, sets of species may be ranked for their tolerances. Several criteria in this system utilize knowledge of tolerance of environmental degradation.

Presence of intolerant species is an important criterion. In each geographic area, some easily identified species are the first to decline with increasing influence by man. Declines may be due to water quality degradation, habitat degradation, or a combination of the two (e.g., high suspended solids loadings and resulting siltation). Examples of intolerant species found in midwestern warmwater streams include (Pflieger 1975; Smith 1979, pers. observ.): blacknose shiner *(Notropis heterolepis)*, southern redbelly dace *(Phoxinus erythrogaster)*, northern Hogsucker *(Hypentelium nigricans)*, silver redhorse *(Moxostoma anisurum)*, rock bass *(Ambloplites rupestris)*, longear sunfish *(Lepomis megalotis)*, banded darter *(Etheostoma zonale)*, and mottled sculpin *(Cottus bairdi)*.

In addition, large families contain species that can be ranked according to their tolerance (Table 3). These rankings are provided as examples. Not all species are listed and both small and large river fish are involved. For obvious reasons, these are preliminary rankings that may need to be modified for use in each geographic area. Knowledgeable local ichthyologists should be consulted in arriving at such rankings. Both species richness and composition are assessed in selected families (e.g., darters, suckers, and sunfish).

Another metric is the presence and abundance of green sunfish, often the dominant or only sunfish present at degraded sites. High abundances of this species (>20% of individuals) indicate degraded conditions. Although I have not included it as a criterion, the presence of johnny darters in the absence of other darters is another indicator of degraded conditions. These most adaptable and tolerant members of their respective families do not peak at the same level, however. The sunfish is clearly more tolerant as it persists at sites long after all darters disappear.

Another related criterion is the presence of hybrids. Hybridization probably occurs as a result of habitat degradation that prevents breeding fish from segregating along normal habitat gradients such as substrate types (Hubbs 1961). This may be common for cyprinids following channelization (Greenfield et al. 1973), although difficulties in recognizing hybrids may preclude using this criterion in cyprinids. Sunfishes also commonly hybridize and the frequency of hybrids seems to increase in modified streams. Finally, in very degraded conditions, hybrids of carp and goldfish become quite common.

(Continued)

Table 3. Ranking of tolerances for selected species of three families of warmwater stream fishes in Illinois. No equivalence between families implied.

	Centrarchidae	Percidae	Catastomidae
Most Tolerant	Green Sunfish	Johnny Darter	White Sucker
	Orange-spotted Sunfish	Orangethroat Darter	Golden Redhorse
	White Crappie	Blacksided Darter	Greater Redhorse
	Black Crappie	Fantail Darter	Black Redhorse
	Bluegill	Slenderhead Darter	Northern Hog Sucker
	Smallmouth Bass	Banded Darter	
	Rock Bass	Iowa Darter	
Least Tolerant	Longear Sunfish		

Again, the species composition and richness metrics used must be weighted according to expectations in the absence of human influences at the same site.

Ecological Factors

All organisms require reliable sources of energy. Indeed, major efforts have been made to measure the many dimensions of productivity. But these efforts are both costly and time-consuming. Thus, a surrogate is needed to provide a first-approximation estimate of production and consumption dynamics. An invaluable index of these dynamics can be obtained by examining the trophic structure of the community. Alterations in water quality or other habitat conditions, including land use in the watershed, commonly result in shifting availabilities of many food resources. Resulting changes in the fish community can then be measured.

Three trophic metrics are used in the present system. I have found that as a site declines in quality, the proportion of individuals that are omnivores increases. The common omnivores of small midwestern streams are *Pimephales notatus* and *P. promelas*, while *Cyprinus carpio* is found over a wider range of stream sizes. The most degraded streams also commonly support large populations of the omnivorous *Carassius auratus* (goldfish). The dominance of these species presumably arises as a result of degradation in the food base, especially invertebrates. As a result, their opportunistic foraging ecology makes them successful relative to more specialized foragers. Generally, I have found that samples with fewer than 20% of individuals as omnivores to be good, while those with over 45% omnivores to be badly degraded.

Another major criterion is the proportion of the community that is insectivorous cyprinids. Generally, a strong inverse correlation exists between abundance of insectivorous cyprinids and omnivores.

Presence of top carnivores is another important indicator. Viable and healthy populations of top carnivore species such as smallmouth bass, walleye, grass pickerel, rock bass, and others indicate a relatively healthy, trophically diverse community. As the quality of the stream declines, these populations decline and disappear. Again, it is assumed that the biologist responsible for assessment will weigh expectations of carnivore populations with knowledge of stream size.

Another criterion that seems to be useful in classifying a site is the frequency of fish with tumors, fin damage or deformities, parasites, and other indicators of disease or anomalies. The Illinois River contains unusual numbers of fish with abnormalities associated with a variety of pollutants (Mills et al. 1966; Sparks 1977). In headwater streams, the frequency of fish (and number of parasites per fish) with the black spots of a trematode parasite (*Neascus* spp.) seems to increase dramatically in modified watersheds.

Another metric that might be used (although I have not used it) is reproductive guilds (Balon 1975). This factor also relates to the presence of hybrids mentioned above. Other uses of reproductive guild information can be expected as knowledge of spawning and nursery area requirements increases.

In addition to use of presence or absence in assessments, it has long been recognized that age structure, growth and recruitment rates, and measures of fish condition can be valuable in assessing the environmental quality of a site. Data in the fisheries literature provide the most extensive data base of any major taxon. Conditions at a site can be evaluated in light of published sources such as Carlander (1969, 1977).

Several of the classification criteria used above depend, in part, on very general attributes of growth and condition of selected fish species. Detailed examination of these patterns requires considerable laboratory work. While such efforts are neither practical nor necessary for most general assessment efforts, they can be developed if more complex assessments are required.

Assumption About Samples

Use of this assessment system assumes that a fish sample represents the entire fish community. It is not sufficient to sample only the large species or the species of sport and commercial significance. The only group of fish that can be excluded is young-of-the-year that are too small to sample with 6-mm mesh seines. These fish are usually ignored because of difficulties involved in sampling and identification. Under some conditions, it may be desirable to evaluate early mortality and larval/fry studies may be warranted. Laboratory identifications will be necessary under these circumstances.

Variation in stream size requires differences in sampling techniques. Each sampling effort must try to obtain a representative sample of all of the fishes in the sample area. Seines seem to be the best sample tool for small, relatively simple streams. As streams increase in size and in complexity of instream cover, it is necessary to use more efficient equipment such as an electric seine. This allows more effective sampling of undercut banks, log piles, and rocky areas where fish escape standard seines. Larger streams require boat-mounted electrofishing equipment and, in some cases, use of nets such as hoop nets. The central theme is to have well-trained biologists exercising sound judgment to insure that a sample is representative of fish at the site.

In addition, it is important to sample the fauna from a representative reach of stream including major local habitat types, such as pools, riffles, and raceway areas. My experience leads me to suggest that a sample from 100 m of stream is sufficient in small streams. In larger streams, selection of several representative pools and riffles rather than standardization by length may be more appropriate. Larger rivers should be sampled in 1-km units when electrofishing equipment is employed.

One of the most difficult problems in using this system is selecting sampling time. Ideally, samples should be taken at several times each year. However, limitations on time and funds may preclude that possibility. In my experience, natural streams tend to be relatively stable seasonally, although exceptions to this generality increase in dry areas. Disturbed areas tend to be more unstable and, thus, the choice of sample times is more critical. At this time, I would select early summer for a primary sample as the least variable period from year to year.

THE CLASSIFICATION PROCESS

The first step in classifying a site is evaluation of the set of factors described above (Table 2). A key problem in classification is defining the baseline. Because of biogeographic and evolutionary circumstances, this can be difficult because expectations vary among systems, even those that have not been modified by man's activities. Headwater streams, for example, generally support fewer species than downstream areas. Warmwater streams support more species than coldwater streams. Consequently, it is not possible to specify precise quantitative criteria for each of the factors at this time, although guidelines based on

experience with midwestern streams are being developed. Thus, a primary challenge to biologists is to circumvent that problem. While the system described here is preliminary, its presentation at this time will stimulate further work and, hopefully, improvement.

Use of the system assumes three major facts:

1. The fish sample, as noted earlier, is a balanced representation of the fish community at the sample site.
2. The sample site is representative of the larger geographic area of interest.
3. The scientist charged with data analysis and the final classification is a trained, competent biologist with considerable familiarity with the local fish fauna.

For each of the criteria, the evaluator assigns a minus (−), zero (0), or plus (+) value to the sample. This approach permits flexibility to accommodate varying evolutionary and ecological histories of fishes among watersheds. As a first step to quantification of this system, I arbitrarily assigned values to each of the grades as follows: (−) = 1, (0) = 3, (+) = 5. These are summed over all criteria for each site to provide an index of community quality. I emphasize that this index is preliminary. It should be used only as a summary along with consideration of the individual metrics on which it is based.

My experience to date leads me to suggest the following tentative ranges for each of the classes. Class boundaries are left vague pending more comprehensive tests of this system. I even hesitate to offer these class boundaries because of concern that they will be accepted uncritically. At the very least, values in the class boundaries must be judged by informed biologists with careful consideration of the individual criteria. Suggested boundaries for the classes are as follows:

Class	*Index Number*
Excellent (E)	57–60
E–G	53–56
Good (G)	48–52
G–F	45–47
Fair (F)	39–44
F–P	36–38
Poor (P)	28–35
P–VP	24–27
Very Poor (VP)	≤ 23

After identification of conditions at a site, problem areas can be evaluated more carefully to assess the factors responsible for degradation. Although no guidelines are yet available, it is likely that careful examination of certain metrics (or sets of metrics) may be used to indicate reasons for degradation (e.g., water quality or habitat structure, overharvest of sport or commercial species). Preliminary explorations of that are in progress.

SOME EXAMPLES

For the past seven years the Black Creek watershed (Allen County, Indiana) has been the subject of a detailed study evaluating the impacts of agricultural practices on water quality (Morrison 1977). As part of that study, I have been evaluating the fish communities at a number of sites throughout the watershed. Most of the streams in the watershed are highly modified as a result of their proximity to croplands. However, one section of Wertz Drain associated with a small woodlot (Wertz Woods) has relatively better water quality and a natural stream channel (Gorman and Karr 1978). To demonstrate the use of this system, the Wertz Woods reach is compared with a stream reach in the intensively managed watershed (Station 6). The sites involved were similar-sized headwater streams.

The Wertz Woods site contained 50% more species and twice as many fish as the more disturbed site (Station 6; Table 4). Other factors suggest that Station 6 is a lower quality station; it supports a higher proportion of omnivores, and suckers and darters are absent. Otherwise, these 2 stations are very similar. According to the 12 criteria outlined above (Table 2), the Wertz Woods site is classed as "Fair" while that at Station 6 is "Poor" (Table 4).

I also classified fish samples from 243 sites in the 7-county area of northeast Illinois. When these data are combined with ongoing studies of several streams in east-central Illinois, a wide array of community classes is available for study. Representative communities were selected from that data set (Table 5b). Seven sample sites are from the Chicago area and one is from east-central Illinois (Jordan Creek). Each site is rated according to the criteria used for the two Black Creek sites.

At one extreme are samples from the Little Calumet River (Station 47) and the Chicago River and Sanitary Ship Canal (Station 54) where 4 and 3 sample efforts, respectively, yielded

Table 4. Species composition and abundances of fishes at two sites in the Black Creek watershed, June 19, 1975.

Taxon	Guild	Station 6	Wertz Woods
CYPRINIDAE			
Campostoma anamalum	Herbivore		1
Semotilus atromaculatus	Insectivore	3	49
Pimephales notatus	Omnivore	21	17
P. promelas	Omnivore	15	3
Ericymba buccata	Insectivore		10
Notropis cornutus	Insectivore		32
N. spilopterus	Insectivore	1	
N. umbratilis	Insectivore	22	
N. stramineus	Insectivore	1	
CATASTOMIDAE			
Catastomus commersoni	Insectivore		7
CENTRARCHIDAE			
Lepomis cyanellus	Insectivore/Piscivore		1
PERCIDAE			
Etheostoma nigrum	Insectivore		2

Table 4. Evaluation of fish communities at two sites in Black Creek, Allen County, Indiana (A); one site in east central Illinois (Jordan Creek, Vermilion County); and nine sites in northeastern Illinois (Chicago area). Quality grades used are minus (-), zero (0), and plus (+). Numbers in parentheses are number of species, individuals, or proportion of individuals, as indicated in column headings. *See text for explanation of classification.*

Station Identification	Stream Size	Number of Species (Total)	Number of Individuals (Total)	Number of Darter Species	Number of Sunfish Species	Number of Sucker Species	Number of Intolerant Species
A. Black Creek, IN							
6	Headwater	0(6)	0(63)	– (0)	– (0)	– (0)	– (0)
Wertz Woods	Headwater	+ (9)	+ (122)	0(1)	– (0)	0(1)	– (0)
B. Illinois							
Jordan Creek	Headwater	+ (18)	+ (153)	+ (3)	+ (3)	+ (3)	+ (4)
Chicago area samples							
86	Midriver	0(13)	– (58)	+ (2)	0(1)	0(1)	+ (2)
219	Headwater	0(16)	+ (239)	+ (2)	0(1)	+ (3)	+ (3)
220	Midriver	0(14)	+ (106)	0(1)	– (0)	+ (2)	+ (2)
33	Midriver	0(17)	+ (223)	– (0)	– (0)	0(1)	– (0)
240	Midriver	– (10)	0(86)	0(1)	– (0)	– (0)	– (0)
39	Midriver	– (8)	– (28)	– (0)	– (0)	0(1)	0(1)
78	Headwater	– (7)	+ (184)	– (0)	– (0)	– (0)	– (0)
47	Midriver	NO FISH IN 4 SAMPLES AT THIS STATION					
54	Midriver	NO FISH IN 3 SAMPLES AT THIS STATION					

no fish. At the other extreme is Jordan Creek with an "Excellent" fish community. The community included many species and individuals, including intolerant species such as *Hypentelium nigricans* (northern hog sucker), *Noturus flavus* (stonecat), *Lepomis megalotis* (longear sunfish), and *Amblopites rupestris* (rock bass). Omnivores were a very small proportion of the community (5%) and insectivorous cyprinids were abundant (42% of individuals).

Two stations (86, 219) from Fox River were classed as "Good" (Table 2). Species richness is depressed from that at Jordan Creek, as is the number of intolerant species and number of sunfish and darter species. Station 219 is somewhat better than Station 86 because of higher total fish densities and more sucker species. Station 86 has low bass abundances and the most tolerant sunfish species, *Lepomis cyanellus* (green sunfish).

The only "Fair" station (220) shown is also from Fox River. Total number of species is similar to the two "Good" stations, but indicators of lower quality are more omnivores, fewer insectivorous cyprinids, more green sunfish, and fewer darters, other sunfish, and suckers.

Two stations (33, 240) from the DuPage River illustrate signs of decay in community quality typical of "Poor" sites. These include depressed species richness (Station 240), high abundance of omnivores, low abundance of insectivorous cyprinids, no intolerant species, and few or none of the less tolerant darters, sunfish, and suckers.

"Very Poor" stations from the Little Calumet (39) and Des Plaines (78) rivers are shown. They represent the extreme of the worst conditions for essentially all of the criteria (Table 5b).

As these examples show, the decline in quality of fish communities across the range of classes is paralleled by declines in several to all of the indices used in the assessment. It is also clear that selection of any one criterion alone yields less reliable results than the array of metrics together.

CONCLUSION

Monitoring fish communities is a viable alternative to physiochemical monitoring programs for assessment of biotic integrity. The subject should receive more attention. I hope that readers will be inclined to test the criteria and approaches outlined here in an effort to improve them. Their outright rejection without provision of an alternate approach will only serve to slow the development of sophisticated biological monitoring programs.

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Proportion of Individuals						Quality	
Omnivores	Insectivorous Cyprinids	Green Sunfish	Top Carnivores	Hybrids	Diseased, etc.	Index	Class
– (57)	+ (43)	+ (0)	– (0)	+ (0)	+ (0)	32	Poor
+ (16)	+ (66)	+ (0)	– (0)	+ (0)	+ (0)	44	Fair
+ (5)	+ (42)	+ (0)	0(3)	+ (0)	+ (0)	58	Excellent
+ (0)	+ (47)	+ (0)	+ (17)	+	+ (0)	50	Good
+ (6)	+ (59)	0(5)	0(1)	+	+ (0)	52	Good
0(25)	0(19)	0(9)	0(1)	+	+ (0)	44	Fair
– (60)	0(23)	0(9)	– (0)	–	+ (0)	28	Poor
– (56)	0(30)	+ (2)	0(1)	+	+ (0)	32	Poor
0(39)	– (13)	– (25)	0(4)	–	+ (0)	24	Very Poor
– (89)	– (0)	0(10)	– (0)	–	+ (0)	22	Very Poor
						0	No Fish
						0	No Fish

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